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ABSTRACT

To assess the effects of school traits on achievement, researchers reanalyzed the data used in "Public and Private Schools" (Coleman et al.) at the school level rather than the individual level. The data for the Coleman report and the present reanalysis are drawn from the "High School and Beyond" study, a 1980 national survey of 30 sophomores in each of 1,002 high schools. The researchers find that using regression equations on aggregate school-level data instead of individual-level data reduces the error in individual-level equations (caused by error in variable measurement) and controls for the contextual effects of student-body socioeconomic status. The reanalysis indicates that the apparent superiority of private schools in academic achievement is much smaller when computed at the school level rather than at the individual level. (Author/RW)

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ACHIEVEMENT PREDICTION WITH SCHOOL LEVEL EQUATIONS: A NON-TECHNICAL EXAMPLE USING THE PUBLIC AND PRIVATE SCHOOLS DATA

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Introductory Statement

The Center for Social Organization of Schools has two primary objectives: to develop a scientific knowledge of how schools affect their students, and to use this knowledge to develop better school practices and organization.

The Center works through five programs to achieve its objectives. The Studies in School Desegregation program applies the basic theories of social organization of schools to study the internal conditions of desegregated schools, the feasibility of alternative desegregation policies, and the interrelations of school desegregation with other equity issues such as housing and job desegregation. The School Organization program is currently concerned with authority-control structures, task structures, reward systems, and peer group processes in schools. It has produced a large-scale study of the effects of open schools, has developed Student Team Learning instructional processes for teaching various subjects in elementary and secondary schools, and has produced a computerized system for school-wide attendance monitoring. The School Process and Career Development program is studying transitions from high school to post-secondary institutions and the role of schooling in the development of career plans and the actualization of labor market outcomes. The Studies in Delinquency and School Environments program is examining the interaction of school environments, school experiences, and individual characteristics in relation to in-school and later-life delinquency.

The Center also supports a Fellowships in Education Research program that provides opportunities for talented young researchers to conduct and publish significant research, and to encourage the participation of women and minorities in research on education.

This report, prepared by the Studies in School Desegregation program, reanalyzes the Public and Private Schools study at the school level rather than at the individual level.

ABSTRACT

Analysis of the effects of school traits on achievement done with aggregate school-level regression equations reduces considerably the error appearing in individual-level equations due to error in the measurement of variables, especially in the measurement of student social status. Aggregate-level equations also control on the contextual effects of student body SES. Aggregate equations are often the logically correct level of analysis, with a more plausible number of degrees of freedom. A reanalysis of the data from the Public and Private Schools report finds that the apparent superiority of private schools (although still overestimated) is much smaller when computed with school-level equations than when estimated at the individual level.

It is common practice in educational sociology to compute regression equations in order to isolate the effect of school characteristics, net of the background of students. The most common use is to isolate the effects of some school factor in the achievement test scores of students. Unfortunately, it is also common practice to criticize such studies on two grounds: (1) the measurement of control variables, whether they are pretest scores of achievement or measures of family socioeconomic status, are made with error. Attentuation of the regression coefficients will have the effect of overstating the impact of any school characteristic which is positively correlated with pretest scores or SES.[1] (2) Analysis must control not only on student SES, but on the contextual effect of the SES of other students. As Coleman et al. (1966) demonstrated, the school student body social class can be quite strongly related to individual student achievement.

One partial solution to these problems is to simply compute regression equations with data aggregated to the school level. There are several advantages to a school-level analysis:

(1) For many such analyses the school is the logical unit of analysis. Often, research is intended to determine whether schools containing some particular characteristic are superior learning environments compared to schools which do not have this characteristic. For tests of statistical significance, the correct number of degrees of freedom in such an argument is the number of schools involved, not the number of students. This is not always the case. For example, if one is evaluating an experimental method of teaching, applied in one school with a second school used as control

group, it is appropriate to set the degrees of freedom equal to the number of students involved. But in this case the object of the experiment is to demonstrate whether a particular treatment as executed in a particular school is superior to a normal situation. It is well understood that such research cannot demonstrate that the application of the same treatment in another school, with another set of implementation characteristics, would produce the same result. Once an educational innovation has gotten past the experimental stage, most research asks a different question: What is the overall effect of this innovation, as implemented in a variety of settings? This question can only be answered by drawing a sample of learning environments (either classrooms or schools) which have this characteristic and contrasting them to a control sample of learning environments which do not. We do not mean to oversimplify the sometimes complex question of assessing the number of degrees of freedom in a research design, but only to point out that in many cases the number of degrees of freedom is the number of learning environments, not the number of students.

(2) Aggregation of data to the school level is necessary in order to compute student body socioeconomic status or average pretest achievement for use as a control variable. Admittedly, this aggregated characteristic of the classroom could be attached to individual student records for an individual level analysis, but even so, aggregation is a necessary prior step.

(3) The aggregation of data to the learning environment level reduces the error of measurement in pretest achievement scores or socioeconomic status. Given economic segregation and segregation of students by ability, the ability or family SES of the other students in a classroom is correlated with an individual's ability or SES. Thus adding the composite classroom

score on a variable increases the accuracy with which an individual's score is measured. For this reason, it is extraordinarily difficult to separate the individual effects of SES on achievement from the classroom contextual effects, because what appears to be classroom contextual effects are partly merely the correction of measurement error in the individual students' SES.

In this paper, we will demonstrate the differences in the results obtained from individual-level and school-level analysis using data from the National Opinion Research Center's High School and Beyond survey, with an analysis similar to that conducted by Coleman, Hoffer, and Kilgore (1981). Their analysis attempted to show that net of family background factors, Catholic and non-Catholic private schools produce higher student achievement than do public schools. They used several analyses, but all had been criticized for three errors:[2] (1) an inability to control for self-selection bias, which might result from either the higher motivation of students attending private schools, or the selection criteria used by private schools to determine which students will attend; (2) failure to correct for attenuation of the regression of achievement on social class variables, which would tend to overstate the achievement benefits attributable to the private schools, which have higher SES students; (3) failure to remove the contextual effects of social class at the same time that the individual level affects were controlled.

Aggregation of the data to the school level can do little to correct for self-selection bias. An analysis of the actual admission criteria of private schools and, ideally, an experiment in which students were randomly assigned to public or private schools seem to be the only techniques which could deal with this issue. Because of this problem, some critics have concluded that it is impossible to assess the relative

quality (measured in achievement outcomes) of public and private schools.[3] An aggregate analysis can, however, incorporate the contextual effects of social class and can reduce the amount of error in the measurement of family background.

Self-selection bias, measurement error, and failure to include contextual SES effects all work to overestimate private school quality. No major biases in the individual-level data work in the opposite direction, so the individual-level regression results are estimates of the upper limit of the effect of private schools. An aggregate analysis does little to correct for self-selection bias, and does not eliminate all measurement error, but it should provide a lower value for this estimate of the upper limit of the private school effect.

The school is also the logically correct unit of analysis. The fact that 30,000 sophomore students were surveyed is misleading. Cronbach (1981) pointed out that there are only 27 non-Catholic private schools in the sample and he argued that this is too small a sample to draw any conclusions about a very heterogeneous pool of schools. The fact that over 500 students were surveyed in these schools is irrelevant.

The Data

High School and Beyond is a survey done in the Spring of 1980, of 30 sophomore students in each of 1,002 high schools, a stratified sample representative of the United States.[4] In analyses, students are weighted to create a sample representative of the national population of sophomores. Added to the stratified sample are data from the 10 academically most successful private schools in the United States.[5] At the same time, seniors in each school were also surveyed, and plans are to follow both cohorts for an indefinite period of time to analyze post-high school adjustment to college and work. The study is in many ways a replication of the earlier

National Longitudinal Study of the High School Class of 1972. Data are from self-administered achievement tests and questionnaires, and are supplemented by a survey of the school principals. Data from the principals are not used in the analysis that follows.

The Original Analysis

Achievement test scores are considerably higher in Catholic and non-Catholic private schools than they are in public schools. However, SES differences are also large, so it is not appropriate to simply conclude that private schools are providing a superior educational environment. One of the analyses conducted by Coleman, Hoffer, and Kilgore, and the one which has received the greatest attention, is a cross-sectional regression of the sophomore sample. Regression equations were computed separately for public school students and private school students, using a large number of family background variables as predictors of achievement. Analysis was done for three achievement tests: vocabulary, reading, and mathematics. In their report, Coleman, Hoffer and Kilgore compute the expected achievement outcomes for public school students which one would obtain by substituting the means for public school students into the regression equations computed on private schools. The differences between these expected values and the actual values of students in public school are a measure of the effectiveness of private schools. An additional dummy variable was added to separate Catholic from non-Catholic schools, so that separate estimates for each could be made.

The Reanalysis

In our reanalysis, we simplified somewhat the procedure used in the public and private schools' report. Rather than running separate equations for public schools and private schools, we ran a single regression equation for the entire population, using dummy variables to isolate the

effects of Catholic and non-Catholic private schools, We used as our measures of family background the same variables used in the original report. Because that list was itself derived from a larger list one might expect that a slightly better equation could be constructed to fit the achievement data for the pooled public-private school sample, but we assumed the differences would be small and were interested in staying as close to the original technique as possible. There is no reason to expect large differences in the estimates of private school effects obtained from the pooled regression equation and those obtained by substituting means from public school equations into private school equations, and as we shall see later, (in Table 2) the differences are small.

We then computed the same regression equations with aggregate data. Here the dependent variable, rather than being the achievement of a single student, becomes the mean achievement of all the students sampled in a particular school. Similarly, the individual father's education is replaced by the mean fathers' education of all students in the school, and so on. If there were no error of measurement and no school contextual effects, the unstandardized regression coefficients would be identical in the aggregate and individual analyses. The standardized coefficients would differ, however, because the standard deviations of the independent and dependent variables would be different at the school level and individual level. Generally, the school-level betas will be higher. But if a variable has measurement error, or if there is a contextual effect in the same direction as the individual effect, then the unstandardized regression coefficient will also be higher at the aggregate level. To demonstrate this in a simplified fashion, Table 1 shows individual and aggregate equations using only three variables. The achievement outcomes are the number of correct answers (corrected for guessing) on tests of

vocabulary, reading, and mathematics. The first six lines of the table apply to the vocabulary subtest. The first two lines show individual and aggregate equations using only the Catholic and other private school dummy variables as independent variables. Because the ownership of the school is a school-level variable, the individual and aggregate analyses must be identical. They differ slightly in this case because of differences in the way missing values were handled at the individual and aggregate level. Although the unstandardized coefficients are almost the same, the multiple R is considerably higher at the aggregate, as expected. In the third and fourth lines we add a single measure of family background--father's education--and the two equations diverge sharply. School mean father's education as a predictor of aggregate student achievement has an unstandardized regression coefficient over twice as large as the parallel individual-level coefficient. Because Catholic and other private schools have higher mean father's educations, a stronger effect of father's education tends to reduce the apparent superiority of private schools. In this case the coefficient for Catholic schools falls to slightly over half of the individual level coefficient and the coefficient for other private schools falls to less than one-fifth of the individual level coefficient. In the fifth and sixth lines of the table we demonstrate the overall effect of controlling on father's education by looking at the ratio of the regression coefficients for Catholic and other private schools to the regression coefficients for these two variables before father's education enters the equation. At the individual level, the coefficient for Catholic schools is slightly less than 3/4 of its uncontrolled coefficient, and for other private schools the coefficient for Catholic schools drops to 3/8 of the uncontrolled coefficient and the coefficient for other private schools is only 1/10th of the individual-level coefficient. In the remaining two panels of the table we see a very similar pattern. Before father's

education is entered, the individual and aggregate coefficients for school ownership are very similar. After father's education is entered, the school ownership coefficients are much lower at the aggregate level than at the individual level, dropping almost to zero for the other private schools. In all cases the multiple correlation coefficient is higher at the aggregate level than at the individual level.

Table 1 About Here

Table 1 demonstrates that the aggregate-level analysis works as expected. In Table 2, we replicate the Coleman, Hoffer, and Kilgore analysis, using the eighteen background variables that they selected. They selected these 18 from a larger pool of variables, choosing those which entered the equation in the expected direction. If we wanted to obtain the best possible pooled individual level equation or the best possible aggregate-level pooled equation, we should make our own selection from the larger pool. However, we want to compare this analysis to the original analysis, we we have retained the original 18 variables. Looking first at the individual level analyses, we see patterns similar to those found in the Coleman, Hoffer, and Kilgore analysis. The apparent superiority of Catholic schools is maintained, and the coefficients are close to the estimates obtained in the original analysis. This is shown in the second and fourth lines from the bottom of the table, which give the ratios of the controlled and uncontrolled regression coefficients for Catholic schools, first from these equations and then from the equations used by Coleman, Hoffer, and Kilgore. For all three subtests, the ratios are similar, although always slightly larger in the original analysis. Apparently the reason for this is that black students in Catholic schools tend to have unusually high achievement. Hence, when the public school means are substituted into private school equations, the effect of a larger

number of black students in the public schools tends not to pull down the overall achievement very much. In the pooled analysis, the achievement of black students is largely determined by the performance of blacks in public schools, since the vast majority are in public schools, so the regression slope for race is steeper than in Coleman, Hoffer and Kilgore's analysis, and somewhat more of the public-private school difference is removed. The first and third lines from the bottom show this pattern for other private schools. Here the differences are somewhat greater, especially in reading, where the original analysis finds a sizeable positive effect on attending other private schools and the present individual level analysis shows very little.

Table 2 About Here

The original analysis reports no significance tests. Obviously, the 30,000 surveyed students do not represent 30,000 independent trials. Formulas to estimate statistical significance from a weighted cluster sample could be used, but we have not done so. To give a rough estimate of significance, we have assumed that each school contributes equally to the analysis (i.e., we have ignored the school weighting) and have assumed that each of the 973 schools with achievement data present is an independent trial. With 973 degrees of freedom in the analysis, there are eight family background variables significant in each equation; six of these are the same for each subtest. Of the fifty-four regression coefficients for the family background variables in the three individual level analyses, only four coefficients have entered in the unexpected direction (for example, father absence seems to increase vocabulary score rather than decrease it). However, none of these four coefficients are significant. Assuming 973 degrees of freedom, the effects of attending non-Catholic

private schools and Catholic schools are not significant in any of the equations.

At the aggregate level, the family background factors enter the equation in somewhat the same manner, but most of the coefficients are larger, reflecting the reduction in error and the increase due to the addition of contextual effects. From nine to twelve variables are significant in each equation. The effects of Catholic and non-Catholic schools are reduced sharply. For non-Catholic schools, all three coefficients are negative, but not significant. For Catholic schools, the coefficients drop to less than half of their values in the individual-level equation, but two of these three coefficients are now statistically significant because of the smaller between-school variance which is being analyzed.

In the original analysis, the use of a large number of family background variables was intended to provide the best possible estimate of an overall family background effect in order to arrive at the least biased estimate of the effects of private schools. Because there is a great deal of multicollinearity in the control variables, the coefficients for individual variables vary considerably across the six equations. For example, the coefficient relating mother's aspirations for the student to math performance is twice as high as the coefficient for the same variable for the vocabulary test, but we doubt that this difference is interpretable. Similarly, the percentage of students with typewriters at home is strongly correlated with aggregate vocabulary test score while individual typewriter ownership is not strongly related to individual vocabulary score, but again we doubt that a substantive interpretation is possible from this analysis. There may be substantive differences between the equations which might be interpreted in an analysis intended for that purpose, but that interpretation of these particular coefficients in this

set of equations seems unwise.)

Earlier we argued that the biases of self-selection, measurement error, and the absence of contextual effects all serve to overestimate the effects of private schooling. The aggregate analysis has reduced but not eliminated measurement error and still ignores self-selection bias, so we believe the private school effects are still overestimated, and think the aggregate coefficients should be viewed as upper limits, rather than unbiased estimates. Thus the main conclusion of the aggregate analysis is that the effects of private schooling probably do not exceed the values obtained in the aggregate equation, which are in turn considerably smaller than those obtained in the individual level. Coleman, Hoffer and Kilgore argue that by including a large number of individual family background variables, they may have overestimated the effects of SES. For example, parental aspirations may have been heightened by the performance of their child in private school, so that parental aspirations cannot be viewed as a prior variable in the analysis. It would be possible to test this argument by running a variety of equations deleting various variables.

Figure 1 plots the mean reading achievement of each school against the best predictor of achievement for that school--the linear combination of independent variables generated by the regression equation. With 852 public schools, it would be difficult to read the plot, so we have simplified the drawing by omitting most of the public school data points. Instead, we have drawn a topographic map of the data. The small closed curve (an irregular oval) drawn with a light solid line represents the area of the graph where the density of public schools is the highest--over 100 schools per square unit of achievement (i.e., one correct question on the reading test). The second solid closed curve represents

the area of next highest density, with over 50 schools per square unit. Six hundred seventy-five schools lie in these two areas. Finally the third and largest irregular oval encloses most of the remaining data points for public schools. In this area, 158 schools are shown by dots. Outside of this third irregular oval are the 19 outliers. Superimposed on this are data points for 82 Catholic schools, shown as solid circles, surrounded by a heavy curve which enclosed all of them. Finally, the 28 non-Catholic schools are shown by +'s and enclosed by a double line. The straight line in the figure is the line generated by the regression equation.

Figure 1 About Here

The plot shows few irregularities. Some of the lowest scores are contributed by non-Catholic private schools. These may be schools catering to students with certain types of learning or behavior problems. Parochial schools lie slightly above the regression line, but since their mean is only .34 units above the expected, the difference is not easily discerned in the plot. There is a slight curvilinearity appearing in the plot--it appears that the best fitting line would be concave upward (i.e., a positive derivative throughout). A regression of the predictor polynomial plus its square does fit the data slightly better, but has no important impact on the results. (In the quadratic equations, one of the private school coefficients becomes significantly negative, and the parochial school coefficients drop slightly.) The plot does illustrate visually the major problem with the attempt to measure the impact of private schools: the higher social status of the student bodies. Of the 82 Catholic schools, 36 have a predicted achievement level of 8 units or higher. Seventeen of the 24 private schools have expected achievement

levels this high, while only 14% of all public schools fall in this range.

Conclusions

Aggregation of data to the school or classroom level should clearly be limited to situations where the independent variable of interest is itself a school or classroom characteristics. But this is often the case in educational research, and when it is, data aggregation is useful to reduce what might otherwise be an unmanageable mass of data. Because it does not solve the problem of self-selection, and only reduces rather than eliminates problems of attenuation through measurement error, we do not want to exagerate its value.

Footnotes

1. There is a good deal written on this: The clearest expositions are in numerous papers by Donald Campbell. See, for example, Campbell and Erlebacker (1970). For a discussion of attenuation, see Guilford (1954).

2. There has been much criticism, most of it as yet unpublished. Society is preparing a symposium on the report, and a paper in that volume (forthcoming) reviews many of the critiques. See also Educational Research Service, 1981.

3. This conclusion is drawn by both Richard Murnane and David Krathwohl in their critiques appearing in Educational Research Service, 1981.

4. The data and codebooks are available from the National Center for Education Statistics.

5. Students in these schools were given very small weights, so that when a weighted analysis is made, the elite schools are essentially discarded.

6. For a lengthy analysis done almost entirely with school-level equations and equations which mix school- and individual-level data, see Crain, Mahard, and Narot (1982).

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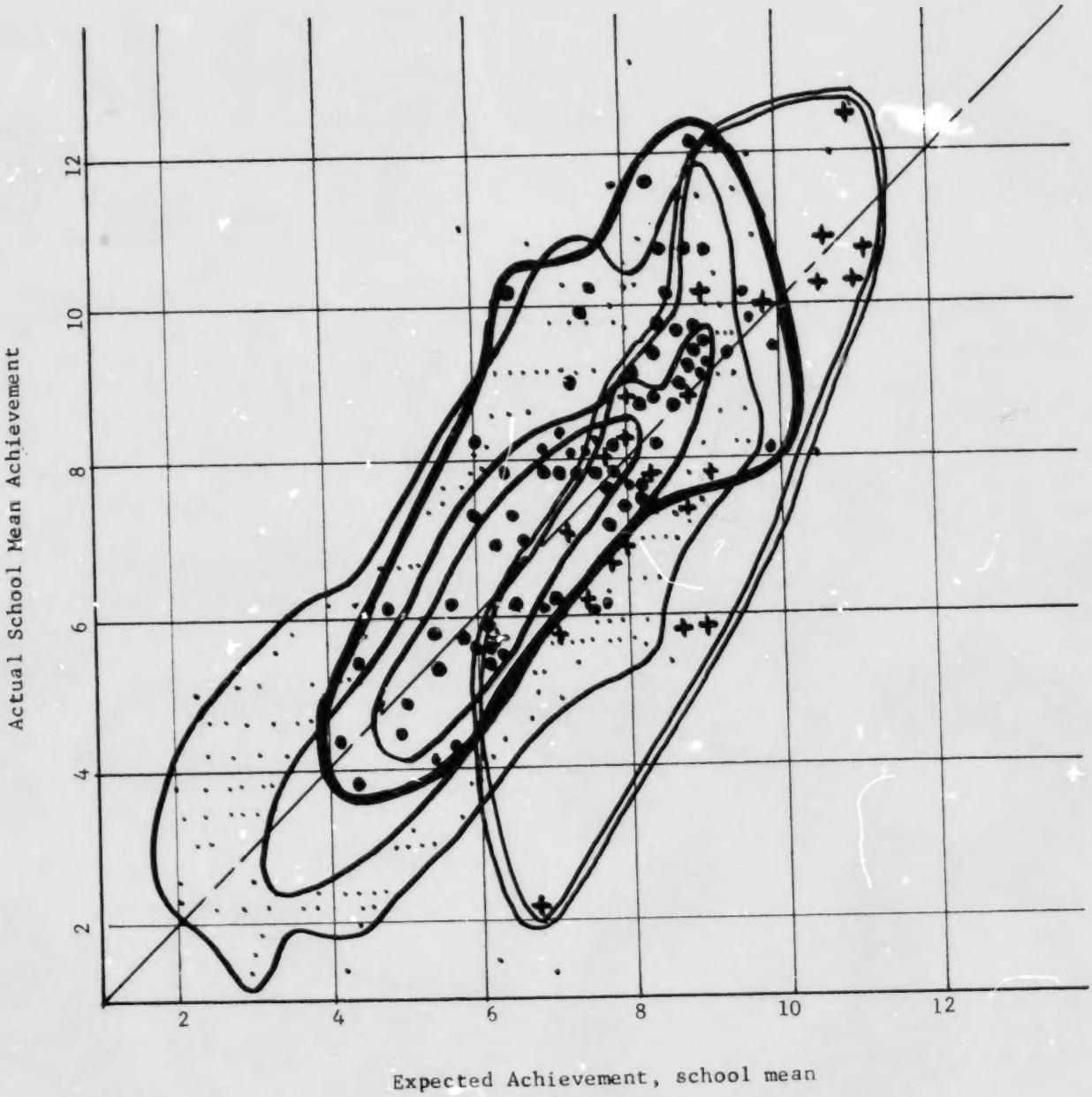

Figure 1: Plot of School-Level Achievement by Predicted Achievement

Table 1: Individual and Aggregate Level Analysis with one Control Variable

Dependent Variable	Level	Regression Coefficients				
		Catholic	Other Private	Father's Education	Constant	Multiple R
Vocabulary	Individual	2.722	2.981	--	8.014	.156
	Aggregate	2.654	3.136		8.015	.327
	Individual	1.943	1.675	.633	5.375	.359
	Aggregate	.994	.299	1.435	2.080	.735
ratio, $\frac{\text{controlled b}}{\text{uncontrolled b}}$	Individual	.72	.56			
	Aggregate	.37	.10			
Reading	Individual	1.940	1.882		6.563	.118
	Aggregate	1.889	1.981		6.565	.296
	Individual	1.336	.868	.492	4.512	.330
	Aggregate	.720	-.017	1.011	2.385	.683
ratio, $\frac{\text{controlled b}}{\text{uncontrolled b}}$	Individual	.69	.46			
	Aggregate	.38	0			
Math	Individual	3.455	3.883		9.630	.136
	Aggregate	3.367	4.091		9.625	.298
	Individual	2.389	2.096	.867	6.017	.330
	Aggregate	1.128	.265	1.935	1.621	.696
ratio, $\frac{\text{controlled b}}{\text{uncontrolled b}}$	Individual	.69	.54			
	Aggregate	.34	.06			

Table 2: Individual and Aggregate Equations, with Full Set of Control Variables

		Unstandardized Regression Coefficients					
		vocabulary		reading		math	
		indiv	agg	indiv	agg	indiv	agg
	$\bar{x}$	8.276	8.254	6.742	6.712	9.965	9.919
Independent Variables	σ	5.232	2.540	4.73	1.909	7.686	3.585
Catholic		1.14	.50*	.70	.34	1.09	.19
Non-Catholic Private		.62	-.14	.08	-.36	.68	-.36
89. Black		3.34*	-3.15*	-2.31*	-2.05*	-4.47*	-3.59*
90. Hispanic		-2.03*	-1.89*	-1.88*	-1.98*	-3.18*	-2.64*
39. Father's Education		.20*	.25*	.15*	.18*	.23*	.23*
42. Mother's Education		.26*	.47*	.20*	.34*	.27*	.63*
101. Family Income		.14	.24*	.04	-.02[a]	.18	.26
103. Rooms in Home		.09	.18*	.08	.25*	.23	.56*
Number of Siblings		-.21*	-.17*	-.14*	-.14*	-.18*	-.15
4I. Own: Calculator		.88*	1.14*	.74*	.88*	1.27*	2.17*
4G. 50+ Books		.90*	1.77*	.62	1.03*	.78	.86
4C. Encyclopedia		.11	.36	.24	.41	.16	.15
4D. Typewriter		.17	1.54*	-.02[a]	.51	.37	1.93*
50A. Aspirations Father		1.03*	.25	1.03*	.20	1.96*	-.18[a]
50B. for Child: Mother		.99	1.97*	1.04*	1.81*	2.06*	4.15*
37C. Mother Before e.s.		-.26	-.90	-.27	-.72	-.52	-.81
37B. worked: During e.s.		-.05	-.49	.01[a]	-.01	.02[a]	-1.23
38B. Father In Home		-.12[a]	-.63[a]	.03	.49	.24	1.35
36D. Mother in Home		.42	1.89*	.46	1.70	.96	3.25*
47G. Talk with Parents		.20	-.13[a]	.23	.33	.17	-.26[a]
Constant		11.77	-2.15	7.63	-1.82	10.52	-7.51
Multiple r		.550	.868	.478	.677	.529	.847
n, unweighed		30,263	973	30,263	973	30,263	973
n, weighted		3,422,479		3,421,054		3,412,433	
Ratio, Controlled b / Uncontrolled b:	Catholic	42%	19%	36%	18%	32%	5%
	Non-Catholic	21%	0%	4%	0%	18%	0%
Ratios from PPS, Table 6.2.1	Catholic	44%		40%		38%	
	Non-Catholic	20%		33%		28%	

*$p < .05$ (see text)

[a]sign in unexpected direction